DIRECTIONAL BIAS IN REPRESENTATIONAL DRAWINGS OF GRASPABLE OBJECTS BY RIGHT AND LEFT HANDERS: THE CONTRIBUTION OF AFFORDANCES VS. BIOMECHANICAL PRINCIPLES

A Thesis

by

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ABSTRACT

This study investigated the orientation of representational drawings of everyday, graspable objects by right- and left-handed adults. Two competing hypotheses were examined. One was an affordance-based hypothesis which predicted that the graspable position of objects would be positioned in the side of space in which they are normally interacted upon. This effect was expected to be enhanced for objects involving self-directed movements (e.g., cup, toothbrush) than object-directed movements (e.g., hammer, tennis racket). The other was a biomechanical hypothesis, which predicted left placement of graspable portion of the objects be drawn by right handers and right placement by left handers, reflecting a greater ease of executions of outward directed movements. Sixty English-speaking right handers and 37 left handers each drew a total of 20 graspable objects. An overall left placement of graspable portions of objects was found, regardless of object movement type. With one exception (jug), the left bias was greater in right handers in 17 of the 20 objects. The results indicate that a biomechanical account provides a better explanation of drawing direction biases than an affordance account.

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INTRODUCTION

Directional biases in human attentional, perceptual, motor, cognitive, and neuropsychological function have been observed in a variety of domains. For example, biases have been noted in initial gaze direction when viewing a face (Hsiao, 2010), in the speed of recognizing a visual event (e.g., de'Sperati & Stucchi, 1997; 2000), in scanning direction of dot patterns (Abed, 1991), in ease of identification of leftward vs. rightward-facing line drawings of objects (Viggiano & Vanucci, 2002), in the perceived expressiveness of left vs. right-oriented pictures of animals (Bennett, Latto, Bertamini, Bianchi, & Minshull, 2010), and in the accuracy of recall of left vs. right facial profile orientation (Jones & Martin, 1997; Martin & Jones, 1999). Directional biases have also been observed in seating preferences (Karev, 2000), in the preferred placement of objects in a frame (e.g., Levy, 1976; McLaughlin & Dean, 1983; Palmer, Gardner, & Wickens, 2008), in the gestural enactment of hand movements (Shanon, 1979), and in the depiction of objects in scenes with or without implied movement (e.g., Dobel, Diesendruck, & Bölte, 2007; Kazandjian, Gaash, Love, Zivotofsky, & Chokron, 2011; Román, El Fathi, & Santiago, 2013; Vaid, Rhodes, Tosun, & Eslami, 2011). A variety of explanations have been advanced for the presence of observed directional biases. The aim of the present study was to examine two potential sources of directional bias in graphic production of representational drawings of objects. The objects to be drawn in the present study were all objects which humans interact with using their hands, that is, they are all graspable objects. Although there exists a sizeable literature on graphic production of various representational figures, e.g., the human face, animals, vehicles, and an assortment of everyday objects, such as teacups, flags, or shoes (De Agostini & Chokron, 2002; Dreman, 1974; Karev, 1999; Kebbe & Vinter, 2013; Lehman & Goodnow, 1975; Nachson & Hatta, 2011; Picard, 2011; Vaid, 1995), the element of graspability has not been systematically isolated for study in previous investigations of drawing directionality. As will become evident, this element provides a useful way of examining two different proposed explanations for the existence of biases in graphic representation.

Biomechanical Influences on Drawing Directionality

Van Sommers (1984) is one of the earliest and most extensive investigations of representational drawing undertaken from an actual graphic production process perspective (i.e., examining how individuals initiate and execute the drawing of lines, circles, planes, etc.). Van Sommers (1984) observed that certain objects tend to be drawn oriented to the left or right. For example, most drawings of facial profiles and cars face leftward while drawings of flags on poles typically face to the right. Van Sommers (1984) considered two possible explanations for this effect. The first was in terms of visual preference, that is, a preference for viewing objects in a certain direction, either due to aesthetic considerations or to exposure to conventionalized representations of familiar objects (e.g., in signs or advertisements). The other explanation was in terms of 'graphic forces' related to the actual execution of the drawing (e.g., starting location, sequencing and direction of movements, orientation, etc.).

With regard to the visual preference explanation, Van Sommers speculated that individuals may tend to draw objects facing in the same direction in which they prefer to view them. To test this, he gave participants a set of 30 cards containing pairs of mirror image line drawings of figures and asked them which orientation looked better to them. Participants were then instructed to sort the cards into five piles based on their degree of preference (indifferent, weak preference to the left/right, strong preference to the left/right). Participant's preference were then compared to their drawings of similar set of objects. The results showed that visual preference could only reliably explain drawing biases for a small set of items (e.g., teacups, scissors). For most of the items tested, people showed a different visual preference for object orientation than the object orientation they displayed in their drawing. Thus, Van Sommers discounted viewing preferences as a viable determinant of biases in drawing directionality.

Van Sommers's other explanation – in terms of 'graphic forces' – was offered as a better explanation of directional biases. Van Sommers noted that directionality biases in graphic production are evident in a number of ways: in where on the drawing page an object is placed (there is a preference to start drawings in the top left side of the page), in starting location on the drawn object itself (there is a preference to begin drawing the salient portion of the object), in the orientation and ordering of strokes (an oblique orientation is preferred) and in the direction of stroke movement (there is a preference for outward directed or extensor movements). Further, his research showed that two of these biases (starting location on the drawn object and stroke direction) have opposite manifestations depending on hand used to draw. Thus, for example, although both right handers tend to draw a profile of a face from the forehead first, because of the greater ease of execution of outward directed movements, right handers tend to end up with left-facing profiles and left-handers with right-facing profiles. These biases relating to the hand used to draw reflect biomechanical principles (Vaid, 1998; 2011) affecting the actual execution of drawing (or what Van Sommers had termed 'graphic forces').

Script Direction as a Type of Biomechanical Influence

Aside from graphic forces another source of directionality in drawings has also been noted and may be considered a special case of biomechanical influences, namely, directional scanning tendencies arising from experience with left-to-right vs. right-to-left written language (e.g., Dobel et al., 2007; Nachson & Hatta, 2001; Naguchi, 2010; Vaid, 1995).

Vaid (1995) observed that on a figure drawing task native readers of Hindi (written and read from left to right) tend to orient animals and vehicles to the left side whereas native readers of Arabic (a right to left writing system) tend to orient the same figures to the right; interestingly, readers with bidirectional reading/writing experience, such as Urdu/English readers, showed no clear preferences (Vaid, 1995). Other studies have replicated this finding of a stronger leftward facing orientation in consistently left-to-right readers as compared to readers with right-to-left reading/writing experience (e.g., Hindi/Urdu, see Vaid, Singh, Sakhuja, & Gupta, 2002; English/Arabic, see Rhodes, 2010; French/Hebrew, see de Agostini & Chokron, 2002; French/Arabic, see Kebbe & Vinter, 2013; German/Japanese, see Taguchi, 2010).

Developmental investigations also support a reading habit account of drawing direction biases in that such biases are either absent or unreliable in children before the age of eight, suggesting that a stable leftward facing bias coincides with the development of literacy in a left to right script (see Picard, 2011; Kebbe & Vinter, 2013). Analogous (though weaker) findings for a rightward facing bias have been noted for children learning to read Hebrew or Arabic (Kebbe & Vinter, 2013; and see discussion in Vaid, 1995).

Reading/writing related biases can in turn interact with hand movement related biomechanical principles, augmenting their influence or conflicting with them. If hand movements directed away from the body midline are easier to execute than those towards the body (Van Sommers, 1984) this effect should interact with whether the preferred writing direction is rightward or leftward. Such an interaction was observed in a speeded dot filling task involving inward vs. outward directed movements with each hand by right handed Hindi vs. Urdu readers (Vaid, 1998).

A recent study by Kebbe and Vinter (2013) followed up on previous studies (e.g., Alter, 1989; Karev, 1999; Picard, 2011; etc.) with a larger range of stimuli and with a direct comparison of left-to-right and right-to-left readers. The stimuli to be drawn included a profile of a face, an animal, a vehicle, and four types of graspable objects: a mug, a hammer, a jug, and a toothbrush (Kebbe & Vinter, 2013). Participants were all right handed but they were asked to draw a side view of each object once with their preferred (right) hand and once with the other hand. The results showed a clear effect of script direction in the facing of the non-tool objects (only the left-to-right readers showed a left facing bias), but no effect of script direction in the drawing of the graspable objects. Instead, these tended to be drawn the same way by left-to-right and right-to-left readers: when drawn using the right hand, the handle tended to be placed rightward for the two self-directed objects (the mug, the toothbrush) but no directional bias was found in drawings of object-directed tools (the jug, the hammer). Moreover, drawing with the non-dominant hand did not change the placement of the mug handle, suggesting that prior experience with the tools prevailed over temporary use of the non-dominant hand in depicting the orientation of a graspable object.

Motor Imagery Hypothesis

An alternative view of directional biases in representational drawings was first proposed by Martin and Jones (1999) in the form of the motor imagery hypothesis, which emphasized handedness-related differences in graphic schemas reflecting how right vs. left handers habitually interact with objects in the world. The motor imagery hypothesis was a precursor to subsequent theoretical accounts framed in terms of object affordances (e.g., Tucker & Ellis, 1998) or embodied cognition (e.g., Barsalou, 2008). What is noteworthy is that handedness was not regarded solely as a proxy for hemispheric functional asymmetries, as was the prevailing practice in the neuropsychological literature of the time, but instead as a form of motoric/cognitive influence on object perception and representation. Martin and Jones arrived at this view based on findings of an association between left handedness and selective memory for rightward profile facing direction of figures on coins and postage stamps. This observation led them to conclude that right and left handers appear to have a different default schema of facing direction in memory as a function of their manual preferences (see Jones & Martin, 1997). Other related work corroborating these effects led Martin and Jones to advocate that further investigations of the scope of handedness effects in cognitive domains beyond memory (or a so-called “chiral psychology of cognition”) was warranted.

A tenet of the motor imagery hypothesis is that there is an isomorphism between sensory and motoric representations of objects. As such, findings in the domain of memory or perceptual identification should find a counterpart in the domain of production. In support of this view, Martin and Jones (1999) reported that – similar to their selective preference for remembering left vs. right-facing profiles, respectively, right and left handers also differed in their direction of drawing profiles.

More recently, Viggiano and Vannucci (2002) carried out a series of experiments to test the motor imagery theory. In one experiment, they compared right and left handers’ perceptual identification of degraded line drawings of left-facing vs. right-facing objects from different semantic categories (animate, inanimate with implied movement, and inanimate without movement). Support was found for Martin and Jones’s (1999) claim of a correspondence between perceptual asymmetries and production asymmetries: right handers were faster at identifying left oriented line drawings of animate figures and inanimate figures with implied movement whereas left handers showed the reverse.

From Motor Imagery Hypothesis to Affordances

Similar to Viggiano and Vanucci (2002), there existed previous studies indicating that individuals are faster at identifying and responding to objects whose graspable end is aligned with the side of space in which the individual's dominant hand would grasp it. For example, de'Sperati and Stucchi (1997) found that participants were faster to predict if a screwdriver was turning in a clockwise or counterclockwise direction when a digital image of a screwdriver was presented at an angle that was more readily "graspable" with the dominant hand. In another study, participants' response times in determining whether common graspable objects were upright or inverted were contingent on the left-right orientation of those objects, even though the horizontal orientation should be irrelevant to response determination. Objects presented in such a way that was compatible with hand use elicited shorter response times and fewer errors than when they were presented in a way that was not compatible with their hand use, providing support for an affordance-related effect (Tucker & Ellis, 1998).

Might directional affordances also come into play to influence the placement of the graspable portion of objects in representational drawings? This question has been addressed by only a few studies to date. In reference to Martin and Jones's (1999) Motor Imagery Theory, according to which a psychophysical isomorphism is expected between how items are represented in reality and in the mind, Viggiano and Vannucci (2002) argued that the graphic representation of tools should be congruent with the hand preferentially used to interact with the tools. That is, right handers should have a mental representation of tools with handles on the right side (as the tools would be if the users are using them) and the opposite should be true for left handers.

Viggiano and Vanucci (2002) tested this notion in a large sample of Italian speaking participants who were asked to draw a total of 246 items, of which 33 were categorized as tools. They noted that most participants (right and left handers alike) drew most objects with the handle on the left (56% of the stimuli). To explain their lack of a handedness effect in tool drawings, Viggiano and Vanucci (2002) remarked on the possibility of extraneous factors, such as the type of movement associated with different tools, as something to control in future investigations. Making reference to other studies that suggested different neural regions implicated in movements made in peripersonal space vs. extrapersonal space, Viggiano and Vanucci suggested that future research compare the representation of objects involving self-directed movements (e.g., hairbrush, razor, etc.) with that of objects that are used to act upon other objects (e.g., hammer, screwdriver). The former would likely involve movement in peripersonal space and the latter would more likely involve movement in extrapersonal space. Hence, Viggiano and Vanucci (2002) proposed that different tools and thereby the tasks associated with the tools may elicit different representational responses; in particular, a stronger graspability effect might be found for objects that are conventionally handled in a more constrained movement relative to the user (e.g., drawing a teacup towards the mouth from the table).

From Van Sommers's (1984) work it is clear that certain graspable objects do show directional biases in drawings (e.g., eyeglasses, scissors, pencils, cups). However, Van Sommers did not systematically present separate analyses for right handers vs. left handers' drawings of these objects. Only a few other studies of graphic production besides those of Van Sommers and Viggiano and Vannucci have examined the facing of objects with handles that are graspable. In these studies only one or two graspable objects were included and (with one exception, Kebbe & Vinter, 2013) there was no *a priori* theorizing of graspability as a variable of interest.

For example, an effect of graspability in drawing task was found for the object jug by Karev (1999). This was the only item (of six items tested) in which the object was positioned solely based on its use: the jug was drawn by right handers with the handle to the right and by left handers with the handle to the left side. Karev (1999) explained the overall directional bias in his study in terms of a laterality account, but to explain the peculiar finding of the jug item, he suggested that the trend of placing the handle towards the dominant hand in the drawings was evidence for a "direct handedness effect," which is arguably another term for graspability, as defined by de'Sperati & Stucchi (1997).

Finally, it is important to note that Van Sommers (1984) reported a congruence between preference for viewing cup handles on the right and for drawing them the same way by right handers, but he did not explicitly report the findings for left handers. Whether the graspability effect is an artifact or a reliable source of directional bias in representational drawings, the present study sought to test this issue directly by comparing right and left handers' drawing of a wide range of tools.

The Present Study

The present study extends prior research by systematically comparing the drawing performance of right versus left handed adults on a range of graspable objects including those involving movements in peripersonal space (i.e., self-directed objects) and those involving movements in extrapersonal space (i.e., object-directed objects). More importantly, drawing direction is examined separately per object to allow for variability in graphic production to be detected. Finally, unlike a previous investigation (Kebbe & Vinter, 2013), where participants were explicitly instructed to produce side view images of the objects, participants in the present study were not instructed to draw in any particular way. This allows us to examine the extent to which a side is preferred and whether the side varies as a function of handedness and object type. Although the study sought to determine whether there would be a directional bias in the drawing of graspable objects, a more important goal was to identify the potential mechanisms that induce the bias.

The present study is designed to examine two competing explanations of drawing direction biases for graspable objects (tools). We refer to these as the affordance account and the biomechanical account.

Affordance Hypothesis

If how an object is represented mentally primarily reflects how the object is normally grasped by the individual, then right and left handers should differ in the side of space in which the object’s handle or graspable portion is positioned. That is, left handers should be more likely to draw handles on the left side of space while right handers should draw them on the right side of space. This effect should be more pronounced for objects involving movements in peripersonal space since these are objects that are more likely to have a prolonged interactional history of use by the user's dominant hand. Moreover, given that left handers have to adapt to using certain objects in a right-handed way, the predicted directional biases in drawing objects should be stronger for right handers than for left handers.

Biomechanical Hypothesis

If the task of drawing objects is primarily influenced by biomechanical principles such as a preference for extensor (outward directed) stroke movements, we would predict that right handers will proceed in a rightward direction while left handers will proceed in a leftward direction. As a result, to the extent that objects are drawn with the graspable side first, a right handle placement bias should emerge for right handers and a left handle placement bias for left handers.

Although extrapersonal vs. peripersonal space considerations are not relevant to a biomechanical account, object type in other respects is relevant: objects with long, narrow handles may be more likely to be drawn with different stroke movements, given prior observations by Van Sommers (1984) of a preference for different orientations of straight lines preferred by right vs. left handers, as compared to those with nonlinear handles. No particular prediction is made with respect to this issue other than to expect variability across objects related to their surface shape.

In summary, the present study was designed to compare the performance of right and left handed adults on free hand representational drawings of 20 graspable objects, including six objects that involve self-directed movements (fork, razor, hair brush, hair dryer, teacup, toothbrush) and 14 that involve other-directed movements (knife, hammer, axe, scissors, screwdriver, wrench, pencil, pliers, saw, drill, racket, jug, spatula, watering can). We examined the relative spatial placement of the handle (left or right side of space) in relation to the user's hand dominance.

METHOD

Participants

Participants were recruited by word of mouth and through an online recruitment website used by Texas A&M University Psychology Department. Most participants were taking an introductory psychology course and were required to participate in research as a part of the course requirements. Ninety-seven participants (41 males), with ages ranging from 17 to 22 (mean age of 18.3) were recruited. Sixty participants were classified as right handers and 37 as lefthanders based on their self-reported hand preferences on an adaptation of the Edinburgh handedness inventory (Oldfield, 1971). All participants had English as their primary and in most cases sole language.

Stimuli

A set of 20 graspable, everyday objects were chosen as target stimuli to be drawn. The object set was selected based on the item list in Snodgrass and Vanderwart (1980) with the stipulation that each object selected had a graspable part (e.g., a handle). The objects included six objects involving movement in peripersonal space (fork, razor, hair brush, hair dryer, teacup, and toothbrush) and 14 objects involving movement in extrapersonal space (knife, hammer, axe, scissors, screwdriver, wrench, pencil, plier, saw, drill, tennis racket, jug, spatula, and watering can). Two letter-size (8 1/2 x 11 inch) unlined, loose sheets of paper and a pencil were used by participants to record their drawing responses. Each sheet contained a grid of ten rectangular boxes (about 4 x 2 inches each), one for each of the objects to be drawn. The sheets were aligned vertically.

Procedure

Informed consent was first obtained from the participants. Then, two response sheets were provided and participants were instructed to draw twenty objects, one in each box, using a pencil. Participants were asked to provide a simple sketch of each object. They were told that the drawings were not going to be judged for their artistic quality. Each object was named aloud by the experimenter in a fixed-random order, and participants were given approximately 30 to 45 seconds to draw each item. The order of naming the objects was as follows: knife, fork, hammer, axe, scissors, screwdriver, wrench, pencil, pliers, saw, razor, hairbrush, drill, tennis racket, jug, hair dryer, teacup, spatula, watering can, and toothbrush.

Upon completion of the drawing task, participants were to indicate on the back of the response sheet 1) what they thought was the purpose of the study, and 2) whether they had had any prior art training. Then, they completed the handedness questionnaire and a few demographic questions and were debriefed.

Data Coding and Analysis

Preliminary inspection of the data revealed that the majority of participants did not guess the purpose of the study. Moreover, the number of individuals with prior art training constituted a small percent of the sample and were not disproportionately represented among a particular handedness group.

The primary independent variable was handedness but additional analyses examined movement type associated with objects (extrapersonal vs. peripersonal space) or handle shape (linear vs. curved). The dependent measure was the handle orientation, which is the location of the handle relative to the head of the object.

In terms of handle orientation, each drawn object was coded in terms of whether the handle (or, where there was no obvious handle, the portion of the object that is typically grasped in using the object) was laterally or vertically positioned, and in the former case, whether the handle was positioned to the left or to the right of the head of the object. Specifically, handle orientation was coded as right, left, or centered depending on the angle of the handle relative to the head (front portion) of the object. For example, if the head of the object was depicted on the left of the page and the handle was placed to the right of the head, the handle orientation was coded as ‘right-oriented’. If the head and the handle of the object were both aligned vertically, the drawing was coded as ‘centered’ (i.e., no preference for right or left orientation). Since the main focus of interest here was lateral orientation, vertically positioned object drawings were not coded further and were excluded from analysis.

A 2 x 2 chi square analysis was performed to compare percentages of right and left object orientation as a function of handedness (right vs. left handers).

RESULTS

Handle Orientation

Binomial Analysis of Handle Placement

To see if the leftward or rightward depiction of objects by right handers and left handers differs from what would be expected by chance, binomial analyses of each of the drawings were computed per handedness group (see Appendix A and B).

For left handers, 9 of the 20 drawings placed the handle to the left significantly greater than chance level: hammer, scissors, wrench, pencil, saw, hair brush, hair dryer, watering can, and toothbrush. For right handers, 18 of the 20 objects showed a significant left placement: knife, fork, hammer, axe, scissors, screwdriver, wrench, pencil, pliers, saw, razor, hair brush, drill, racket, jug, hair dryer, spatula, and toothbrush (only teacup and watering did not show a significant difference) .

Chi Square Analysis of Handle Placement: Right vs. Left

To determine if there was a significant placement of the handle to the left or to the right, chi square analyses were conducted for each drawn item separately per group. Significant directional effects were found for six of the 20 objects: fork, $\chi 2$ (1, N = 52) = 5.13, $p< 0.05$; pliers, $\chi 2$ (1, N = 60) = 7.75, $p< 0.05$; razor, $\chi 2$ (1, N = 60) = 5.71, $p< 0.05$; tennis racket, $\chi 2$ (1, N = 73) = 16.13, $p< 0.05$; jug, $\chi 2$ (1, N = 77) = 4.59, $p< 0.05$; and spatula, $\chi 2$ (1, N = 70) = 9.35, $p< 0.05$. A leftward bias in handle depiction characterized 73.7% of right handers and 63.0% of left handers. For right handers, the only two items that did not show a leftward bias in handle placement was the item jug (here only 30.4% depicted the handle on the left) and teacup (here only 36.8% of right handers depicted the handle on the left). For all other items, right handers showed a leftward placement of the handles (see Appendix C).

In general, in comparison to right handers, left handers exhibited less of a directional bias, with approximately equal chance to depict a handle to the left or to the right of the page in their drawings.

Effect of Movement Associated with Tool Type

A 2 x 2 mixed factorial ANOVA was computed to investigate the interaction between movements associated with objects that are other-directed (extrapersonal space) vs. self-directed (peripersonal space) and handedness. The dependent measure was the percentage of left-oriented objects (out of a total of left vs. right oriented objects). There was no main effect of object type [$F(1, 95) = .40$, $p > .05$, $\eta^2 = .004$] and no interaction effect between type of object and handedness, $F(1, 95) = 1.09$, $p > .05$, $\eta^2 = .01$. The only effect was a main effect of handedness, $F(1, 95) = 5.00$, $p < .05$, $\eta^2 = .05$, whereby right handers showed a significantly higher percentage of left-handle-oriented drawings than left handers.

DISCUSSION

The present research sought to examine directional biases in the placement of object handles (to the left or right side of space) as a function of handedness. Specifically, the study was designed to compare two differing predictions regarding how graspable objects would be depicted in representational drawings by right versus left handers. The first prediction, derived from an affordance perspective, was that right handers should preferentially place the handles of tools on the right side of the page and the opposite should be observed among left handers. The other prediction, derived from a biomechanical perspective, was that items should be drawn starting from the leftmost part of the item and proceeding in an outward (extensor) direction. If the starting point is with the handle, the handle will end up being oriented leftward by drawings made by right handers but will end up oriented rightward by drawings made by left handers.

Our results do not provide support for the affordance hypothesis. With one exception, right handers did not tend to draw handles to the right side of space. Instead, they showed a strong *left* placement bias. For most drawings, most participants, independent of their handedness, drew the handles on the bottom left of the space. Right handers were in fact significantly more left oriented than left handers (the only item not left-oriented for right handers was the jug). On average 71.5% of right handers tended to orient the handles of 17 of the 20 objects to the left while 59.97% of left handers demonstrated a left-oriented pattern for 15 items.

Object Type Effects

Unlike the general pattern of leftward handle placement that characterized the performance of right handers for the majority of objects with straight and narrow handles, a different pattern emerged when considering curved handles for containers.

Depicting Jugs, Teacups, and Watering Cans

Following Van Sommers's (1984) suggestion, we examined directional bias in object drawing item by item for the production of each item may exert different execution demands. Three objects are particularly interesting in this regard: jug, teacup, and watering can. These objects share similarities that the other stimuli in the experiment do not: they are all containers and are conventionally depicted with the open end upward as if constrained by gravity (so as to hold the matter in the container). Unlike other tools (e.g., axe, hammer, etc.) that can be oriented in any angle (i.e., with higher degrees of freedom in orientation), we observed that participants drew jugs, teacups and watering cans with the container end facing up.

Furthermore, with respect to depiction of the handle, the jug was one of the few items for which we found a hand preference effect. In support of Karev (1999), Picard (2011), and Vaid and Chen (2009), we found that right handers were significantly more likely than left handers to depict the jug handle to the right (60.38%) while left handers showed a weak preference or no preference for the positioning of the handle (45.16% drew the handle to the right, slightly below chance level). This pattern was again observed with the teacup, with right handers preferring to depict the teacup handle to the right (62.07%), while left handers did not show a clear preference (55.56%; the handedness difference here was not significant).

The results for the watering can, however, were different from the other two objects: for this item neither group showed a left bias (only 38.33% of right handers and 31.43% of left handers showed left placement of the handle). The difference between the watering can and the other two objects may be attributed to the additional component in the watering can – watering cans have a relatively long spout while jugs have short spouts and teacups have none. If drawing begins with the main body and ends with the furnishing of details (e.g., such as spouts, handles, etc., Van Sommers, 1984), then perhaps the additional component of a spout in a watering could have modulated the object graspability effect that Karev (1999) and others observed in drawings of cups and similar items (see also Rhodes, 2010, for a similar argument for the drawing of teapots). Table 4 (Appendix D) provides a summary of our results on these items and results for similar items in previous studies.

Graspability Effect

In summary, our findings did not support a graspability effect based on the Motor Imagery Hypothesis (Martin & Jones, 1999). Based on this hypothesis, a state of psychophysical isomorphism should exist in the way people interact with objects and their mental representation of those objects. In the present context, when the participants draw a tool, they should activate motor representation of the way in which the tool was to be interacted with. Given that left handers and right handers differ in their handedness and, consequently, have a different motoric experience of using tools, the representations of left handers and right handers should be different. Specifically, right handers tend to grasp handles with their right hand and a consistent motor representation of the handle to the right should be formed, and vice versa for left handers. However, our findings did not support this prediction. Instead, both groups showed a tendency to portray the handle to the left, with right handed participants showing a stronger tendency for such a leftward bias while left handers showing less of a bias. Therefore, right handers oriented the tool handles in a *less* graspable manner while left handers showed a less consistent pattern. While other studies (reviewed above) have demonstrated that facing of specific objects (e.g., a jug, a cup) is influenced by handedness (e.g., Karev, 1999), thereby supporting the Motor Imagery Hypothesis and the graspability effect (de'Sperati & Stucchi, 1997, 2000), our findings do not show support for such an effect when a larger set of stimuli are used.

It is possible that the lack of support for a graspability effect in our study reflects the fact that participants were not given any particular instructions to visualize using the object before drawing it. Flusberg and Boroditsky (2010) noted that motor representations may be activated only when an agent is acting on the object, not when the object is moving by itself. As the instructions given to the participants in our study were simply to sketch the objects (as opposed to "sketch the object as you would imagine using it"), participants might not have been likely to activate the motor imagery associated with interaction with the objects. That is, the representation of the items activated while the participants were drawing was independent of the way they handle the object with their hands. Thus, it could be that the decontextualized presentation of the stimuli in the present study obscured any effects related to motor imagery that may have otherwise been activated (see Borghi, Flumin, Natraj, & Wheaton, 2012, for evidence of the importance of context in the emergence of object affordance effects). Thus, in future work it will be important to provide a better test of the motor imagery view by making the activation of motoric information more salient before the participants engage in drawing. Interestingly, in the Kebbe and Vinter (2013) study, participants were given instructions to visualize interacting with the object. Their results (for the item jug) support a graspability account (right handers placed the handles to the right, even when drawing with their left hand). Since the present study did not contain such instructions, our failure to support a graspability effect for most stimuli used in the current study may reflect this limitation of our design.

Extrapersonal vs. Peripersonal Objects

Viggiano and Vanucci (2002) advised that the task associated with tool use should be examined in relation with handedness, specifically, whether the movement associated with use of a particular tool is directed towards the body (i.e., peripersonal space) or away from the body (extrapersonal space).

As such, we analyzed the drawing orientation of our stimuli as a function of this variable. Comparing the number of right-oriented peripersonal tools (razor, fork, hair brush, hair dryer, teacup, and toothbrush) and right-oriented extrapersonal tools (e.g., knife, hammer, axe, scissors, screwdriver, wrench, pencil, pliers, saw, drill, tennis racket, jug, spatula, and watering can) between right and left handers, we found no reliable differences between right handers and left handers in object orientation based on tool type. Thus, our findings did not support Viggiano and Vanucci's (2002) speculation. It would appear that the type of movement associated with an object is not a relevant factor influencing how the object tends to be depicted.

Limitations

A number of limitations of the present study should be noted. One that has already been mentioned is that we did not emphasize in the instructions that participants should imagine using the objects before drawing them. As suggested in Flusberg and Boroditsky (2010), instructing participants to draw the tool as they imagine using the tool might have led to activation of motor information, a crucial factor in eliciting a motoric effect of graspability. In future research it will be important to build in this manipulation.

A second limitation is that the number of participants, particularly, left handers, in the current study was relatively low. We only had 97 overall participants (including 37 left handers) while previous researchers such as Karev (1999) had over 750 total participants. Increasing the sample of left handers will allow a better assessment of their performance. Furthermore, adding a group of individuals with "mixed" handedness (that is, individuals who do not show a clear hand preference in using certain objects) could also be useful in clarifying the role of handedness in object depiction.

Another important limitation of the present study is that we did not systematically code for starting position or stroke direction for each drawing as was done in previous studies (e.g., Van Sommers, 1984; Picard, 2011). Given previous findings that starting location makes a difference in whether a given object will end up facing rightward or leftward, it is crucial to code for this aspect to more fully understand why particular drawings ended up with the orientation that they did, and whether right and left handers in fact differed in their starting position and/or stroke direction, as would be predicted based on biomechanical considerations.

Finally, Viggiano and Vanucci (2002) noted that they could not generalize a handedness effect to tools due to the scant number of tool stimuli (n=33). Our study also faced the same problem. We had only seven peripersonal stimuli. Perhaps if we had included a larger number of items, particularly peripersonal ones, a difference might have emerged.

CONCLUSIONS

In the present study, we aimed at exploring the role of handedness in the drawing of graspable objects. We predicted that individuals' representations of graspable objects would be influenced by their hand use. Specifically, we predicted that handles of graspable objects would be oriented in the direction of the participants' dominant hand, reflecting a tendency to interact with the object with that hand (i.e., the graspability effect). While the drawings of certain objects (e.g., jug, teacup) appeared to support our prediction, as a whole, our participants exhibited a leftward orientation bias in their drawings, that is, drawing the handles of most objects facing toward the left side of the page. This was especially the case for right handers, even though this was the group that we expected to show the strongest rightward orientation bias based on graspability considerations. Instead, counter to our prediction, right handers in our study showed an even stronger leftward orientation bias in depicting handles as compared to left handers.

Thus, with the exception of the single item (jug), which corroborated a similar handedness effect on this item by Karev (1999) and others, our study as a whole did not support the graspability hypothesis. It is possible that we may have gotten a different pattern of results had we emphasized the graspability dimension more overtly in our instructions. This possibility should be examined in future research.

The fact that most objects were depicted (by right and left handers alike) with the handle on the left suggests either that there are certain canonical conventional (aesthetic) preferences for how objects should be depicted or that participants are implicitly being influenced by writing direction biases – since both right and left handers drew the salient element on the left side and moved in a rightward stroke direction. In future research, it would be important to test right-to-left language users (e.g., Arabic readers) to investigate whether the results we obtained – of an overall left-bias in the placement of handles – reflects a left-to-right reading/writing direction influence of our sample. Several other studies of graphic production have observed an effect of reading/writing habits using a variety of figures (e.g., Taguchi & Noma, 2005; Vaid, 1995; see Vaid, 2011, for a review). We would expect that graspable objects should also be susceptible to such an effect.

To conclude, our study found that graphic production of graspable objects is in part influenced by manual preference but only for certain items and that the predominant pattern supports a biomechanical account of drawing direction biases.

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APPENDIX A

Table 1. *Binomial Test Results for Right vs. Left Placement of Handles by Left Handers.*

		n	Observed Prop.	p
Knife	Right	14	0.39	0.24
	Left	22	0.61	
		36		
Fork	Right	10	0.45	0.83
	Left	12	0.55	
		22		
Hammer*	Right	11	0.30	0.02
	Left	26	0.70	
		37		
Axe	Right	11	0.32	0.06
	Left	23	0.68	
		34		
Scissors*	Right	6	0.24	0.02
	Left	19	0.76	
		25		
Screwdriver	Right	8	0.42	0.65
	Left	11	0.58	
		19		

Table 1. Continued

		n	Observed Prop.	p
Wrench*	Right	7	0.26	0.02
	Left	20	0.74	
		27		
Pencil*	Right	8	0.26	0.04
	Left	20	0.74	
		28		
Plier	Right	10	0.45	0.83
	Left	12	0.55	
		22		
Saw*	Right	7	0.20	0.001
	Left	28	0.80	
		35		
Razor	Right	10	0.56	0.82
	Left	8	0.44	
		18		
Hair Brush*	Right	9	0.29	0.03
	Left	22	0.71	
		31		

Table 1. Continued

		n	Observed Prop.	p
Drill	Right	11	0.34	0.11
	Left	21	0.66	
		32		
Racket	Right	13	0.5	1.00
	Left	13	0.5	
		26		
Jug	Right	17	0.55	0.72
	Left	14	0.45	
		31		
Hair Dryer*	Right	10	0.28	0.01
	Left	26	0.72	
		36		
Teacup	Right	16	0.44	0.62
	Left	20	0.56	
		36		
Spatula	Right	12	0.52	1.00
	Left	11	0.48	
		23		

Table 1. Continued

		n	Observed Prop.	p
Watering Can*	Right	11	0.31	0.04
	Left	24	0.69	
		35		
Toothbrush*	Right	9	0.27	0.01
	Left	23	0.73	
		33		

Note: Binomial test probability level at $p<.05$

APPENDIX B

Table 2. *Binomial Test Results for Right vs. Left Placement of Handles by Right Handers.*

		N	Observed Prop.	p
Knife*	Right	20	0.34	0.02
	Left	39	0.66	
		59		
Fork*	Right	5	0.17	0.001
	Left	25	0.83	
		30		
Hammer*	Right	19	0.32	0.001
	Left	41	0.68	
		60		
Axe*	Right	13	0.23	0.001
	Left	44	0.77	
		57		
Scissors*	Right	7	0.19	0.001
	Left	30	0.81	
		37		
Screwdriver*	Right	9	0.20	0.001
	Left	36	0.80	
		45		

Table 2. Continued

		N	Observed Prop.	p
Wrench*	Right	9	0.18	0.001
	Left	42	0.82	
		51		
Pencil*	Right	15	0.33	0.04
	Left	30	0.67	
		45		
Pliers*	Right	5	0.13	0.001
	Left	33	0.87	
		38		
Saw*	Right	13	0.22	0.001
	Left	46	0.78	
		59		
Razor*	Right	10	0.24	0.001
	Left	32	0.76	
		42		
Hair Brush*	Right	9	0.16	0.001
	Left	46	0.84	
		55		
Drill*	Right	13	0.25	0.001
	Left	40	0.75	
		53		

Table 2. Continued

		N	Observed Prop.	p
Racket*	Right	4	0.09	0.001
	Left	43	0.91	
		47		
Jug*	Right	14	0.30	0.01
	Left	32	0.70	
		46		
Hair Dryer*	Right	13	0.22	0.001
	Left	46	0.78	
		59		
Teacup	Right	21	0.37	0.06
	Left	36	0.63	
		57		
Spatula*	Right	8	0.17	0.001
	Left	39	0.83	
		47		
Watering Can	Right	23	0.40	0.15
	Left	35	0.60	
		58		
Toothbrush*	Right	7	0.12	0.001
	Left	52	0.88	
		59		

Note: Binomial test probability level at $p < .05$

APPENDIX C

Table 3. *Handedness Differences in Percent Left Placement of Handle by Item.*

		Right Handers	Left Handers	
		%	%	
Extrapersonal	Knife	66.10	61.1	ns
	Hammer	68.33	70.27	ns
	Axe	77.19	67.65	ns
	Scissors	81.08	76.00	ns
	Screwdriver*	80.00	57.89	p <.067
	Wrench	82.35	74.07	ns
	Pencil	66.67	71.43	ns
	Pliers*	86.84	54.55	p <.005
	Saw	77.97	80.00	ns
	Drill	75.47	65.63	ns
	Tennis Racket*	91.49	50.00	p <.001
	Jug*	30.43	54.84	p <.032
	Spatula*	82.98	47.83	p < .002
	Watering Can	60.34	68.57	ns
Peripersonal	Fork*	83.30	54.55	p < .024
	Razor*	76.19	44.44	p < .017
	Hairbrush	83.64	70.97	ns
	Hair Dryer	77.97	72.22	ns
	Teacup	36.84	44.44	ns
	Toothbrush*	88.14	72.73	p <.06

Note: Percentages based on total number of participants who showed either a rightward or leftward bias

APPENDIX D

Table 4. *Effect of Handedness on Handle Placement of Jug and Teacup across Studies.*

		Right Handers		Left Handers	
		Total N+	% Handle on Right	Total N	% Handle on Right
Jug	Our study	46	69.56	31	45.16
	Karev (1999)*	264	92.80	270	64.07
	Picard (2011)†	20	80.00	20	35.00
Teacup	Current Study	57	63.16	36	55.56
	Vaid & Chen (2009)	125	84.00	58	62.10
	Picard (2009)†	20	90.00	20	35.00
Teapot	Rhodes (2010)*	53	33.70	28	24.30

+ Total number of participants who showed either a leftward or rightward placement
* Statistics calculated by deducting 100 percent with the percentages handle on left
† 9 years old participants, first of two drawings of the object

APPENDIX E

Table 5. *Distribution of Handle Orientation (Left vs. Right) by Handedness (Right Handers and Left Handers).*

			Count				Percentage		
Item	Chi Square	p		Right	Left	Total		Right	Left
Knife	0.242	0.623	RH	20	39	59	RH	33.90	66.10
			LH	14	22	36	LH	38.89	61.11
				34	61	95			
Fork	**5.125**	**0.024**	RH	5	25	30	RH	16.67	83.33
			LH	10	12	22	LH	45.45	54.55
				15	37	52			
Hammer	0.4	0.841	RH	19	41	60	RH	31.67	68.33
			LH	11	26	37	LH	29.73	70.27
				30	67	97			
Axe	0.999	0.317	RH	13	44	57	RH	22.81	77.19
			LH	11	23	34	LH	32.35	67.65
				24	67	91			
Scissors	0.232	0.6	RH	7	30	37	RH	18.92	81.08
			LH	6	19	25	LH	24.00	76.00
				13	49	62			
Screwdriver	**3.346**	**0.067**	RH	9	36	45	RH	20.00	80.00
			LH	8	11	19	LH	42.11	57.89
				17	47	64			
Wrench	0.742	0.389	RH	9	42	51	RH	17.65	82.35
			LH	7	20	27	LH	25.93	74.07
				16	62	78			

Table 5. Continued

Item	Chi Square	p		Count: Right	Count: Left	Count: Total		Percentage: Right	Percentage: Left
Pencil	0.181	0.67	RH	15	30	45	RH	33.33	66.67
			LH	8	20	28	LH	28.57	71.43
				23	50	73			
Pliers	**7.751**	**0.005**	RH	5	33	38	RH	13.16	86.84
			LH	10	12	22	LH	45.45	54.55
				15	45	60			
Saw	0.054	0.816	RH	13	46	59	RH	22.03	77.97
			LH	7	28	35	LH	20.00	80.00
				20	74	94			
Razor	**5.714**	**0.017**	RH	10	32	42	RH	23.81	76.19
			LH	10	8	18	LH	55.56	44.44
				20	40	60			
Hairbrush	1.923	0.166	RH	9	46	55	RH	16.36	83.64
			LH	9	22	31	LH	29.03	70.97
				18	68	86			
Drill	0.955	0.33	RH	13	40	53	RH	24.53	75.47
			LH	11	21	32	LH	34.38	65.63
				24	61	85			
Racket	**16.13**	**0.001**	RH	4	43	47	RH	8.51	91.49
			LH	13	13	26	LH	50.00	50.00
				17	56	73			

Table 5. Continued

Item	Chi Square	p		Count				Percentage	
				Right	Left	Total		Right	Left
Jug	**4.586**	**0.032**	RH	32	14	46	RH	69.57	30.43
			LH	14	17	31	LH	45.16	54.84
				46	31	77			
Hair Dryer	0.402	0.526	RH	13	46	59	RH	22.03	77.97
			LH	10	26	36	LH	27.78	72.22
				23	72	95			
Teacup	0.532	0.466	RH	36	21	57	RH	63.16	36.84
			LH	20	16	36	LH	55.56	44.44
				56	37	93			
Spatula	**9.351**	**0.002**	RH	8	39	47	RH	17.02	82.98
			LH	12	11	23	LH	52.17	47.83
				20	50	70			
Watering Can	0.637	0.425	RH	23	35	58	RH	39.66	60.34
			LH	11	24	35	LH	31.43	68.57
				34	59	93			
Toothbrush	**3.497**	**0.061**	RH	7	52	59	RH	11.86	88.14
			LH	9	24	33	LH	27.27	72.73
				16	76	92			

APPENDIX F

SAMPLE DRAWINGS BY A LEFT HANDED PARTICIPANT

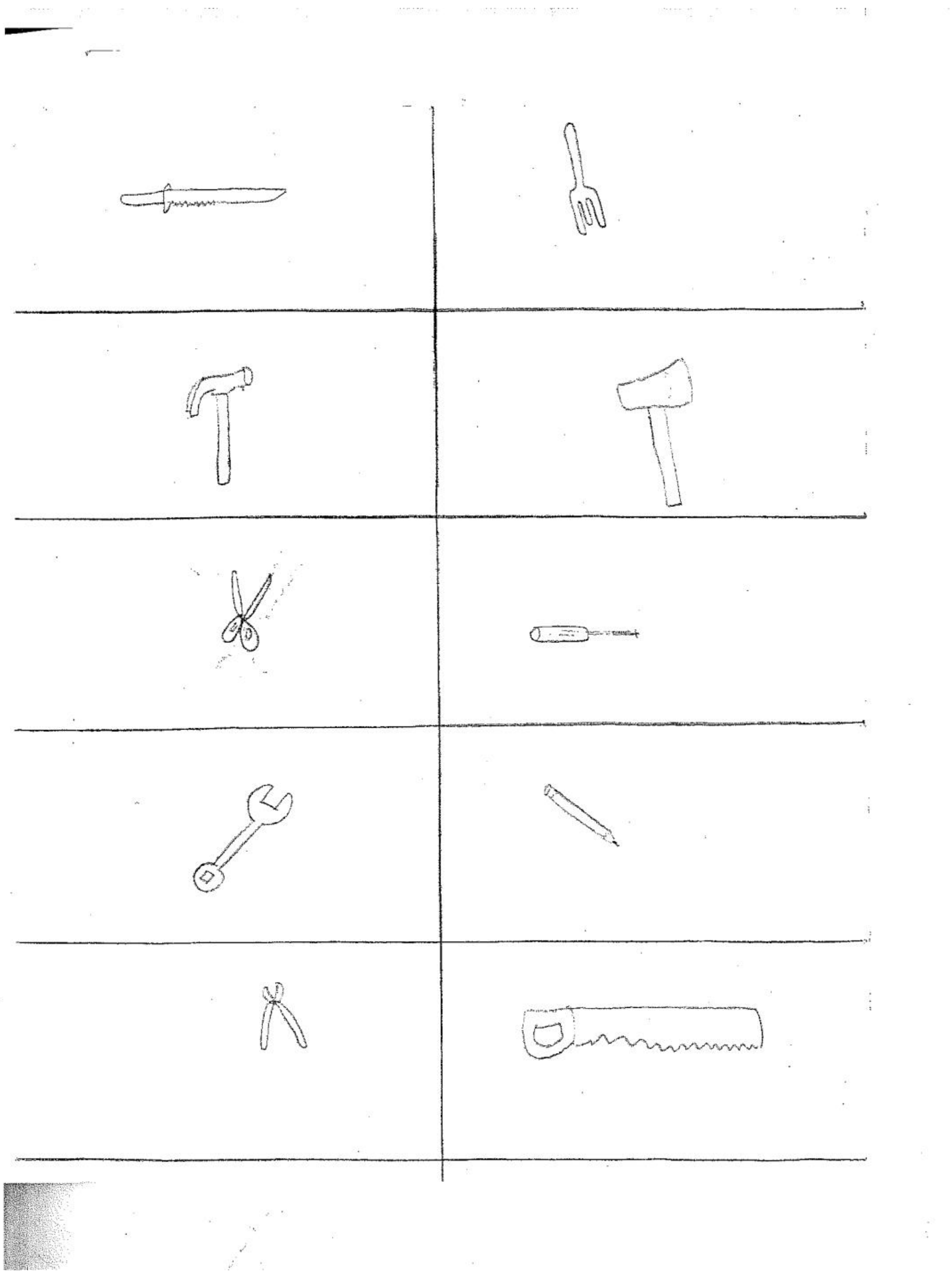

Figure 1. First ten items of the object set drawn by a left hander.

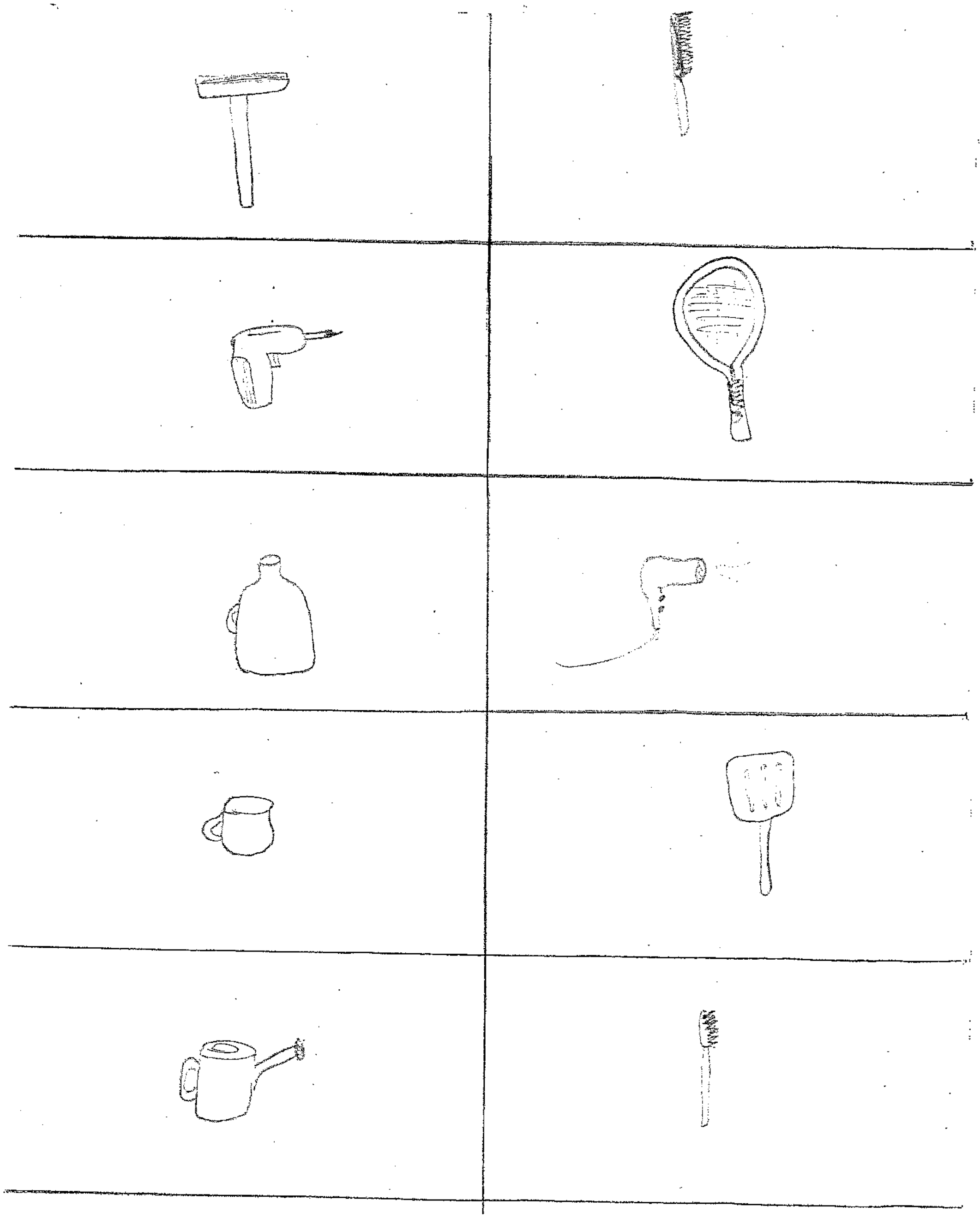

Figure 2. Last ten items of the object set drawn by a left hander.

APPENDIX G

SAMPLE DRAWINGS BY A RIGHT HANDED PARTICIPANT

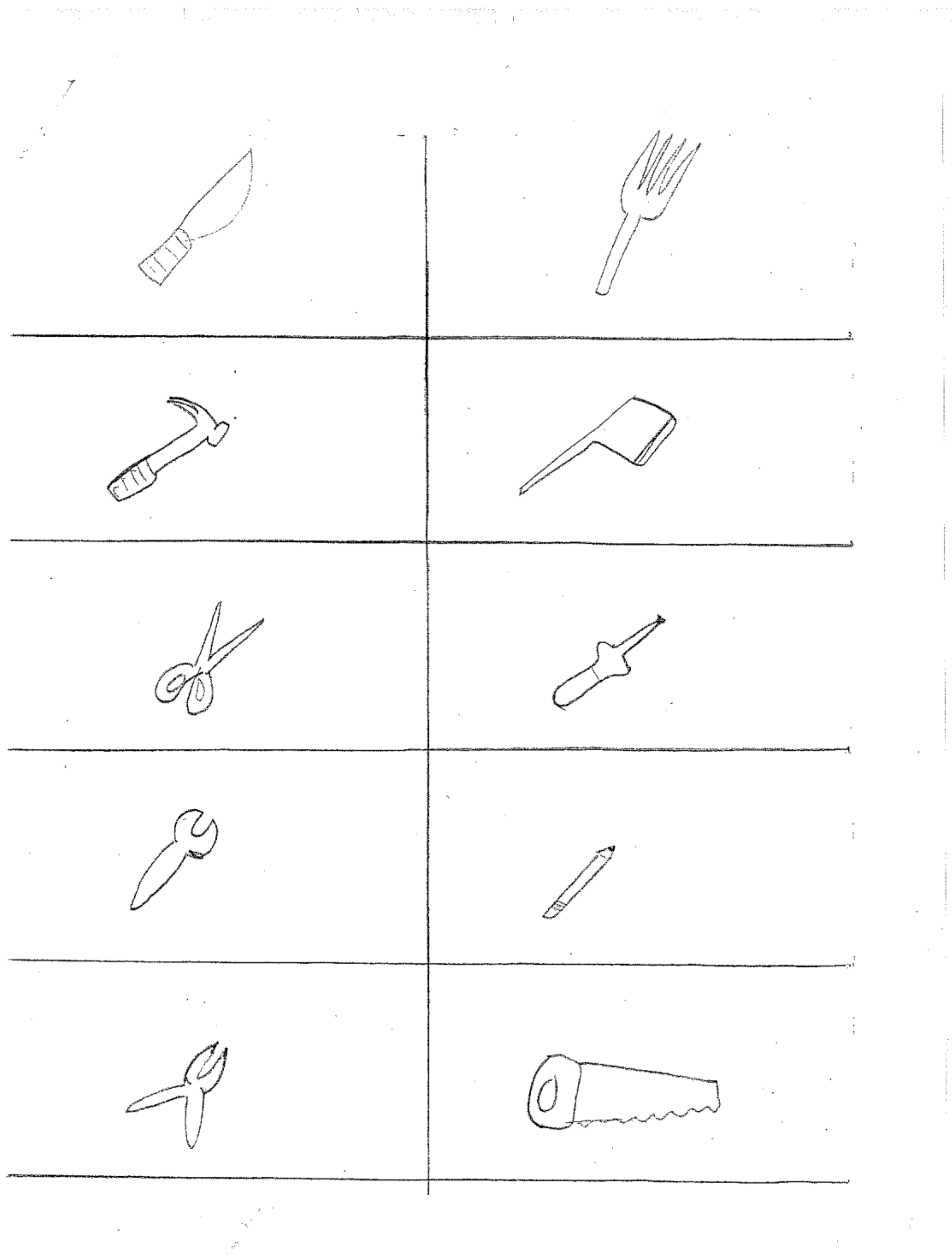

Figure 3. First ten items of the object set drawn by a right hander.

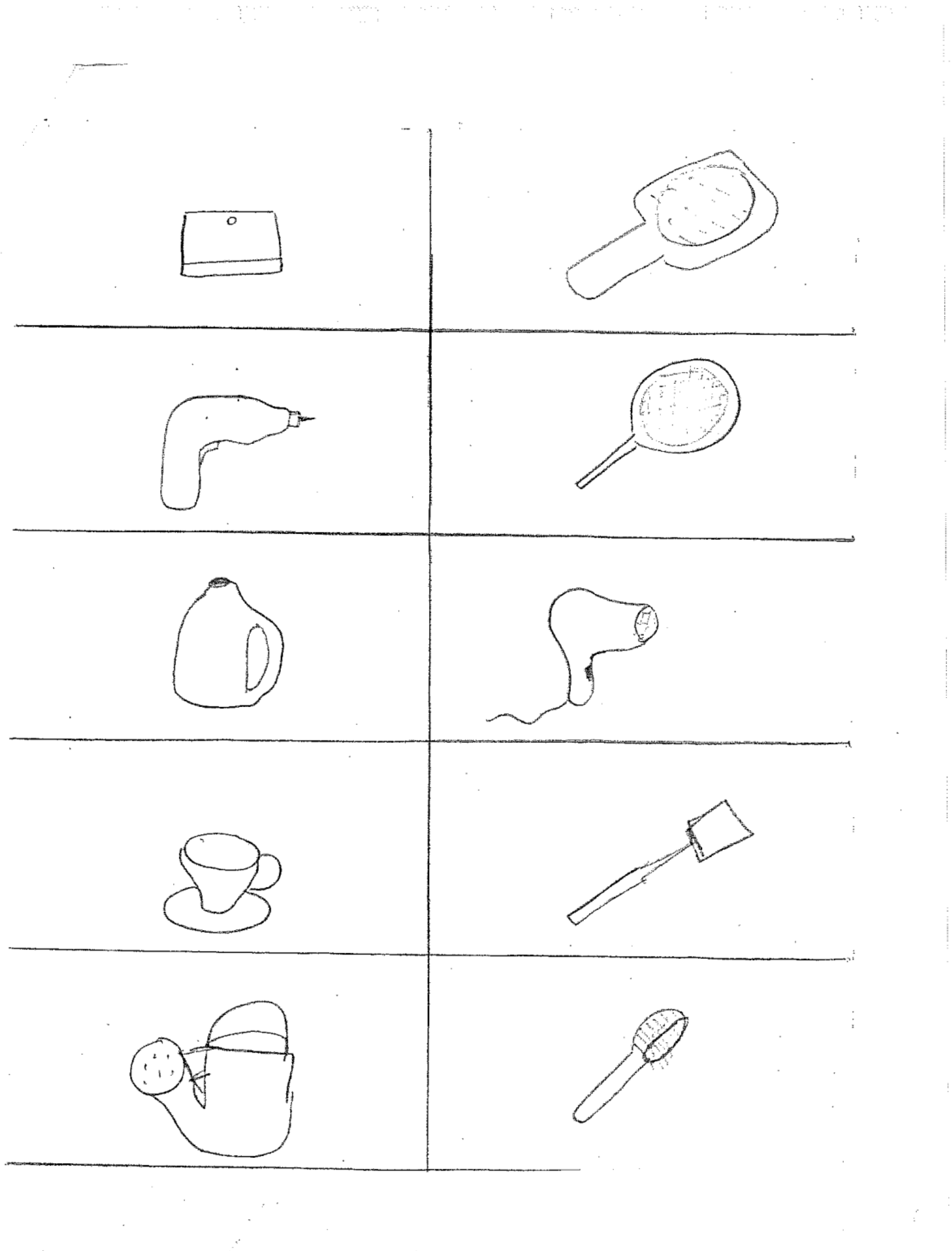

Figure 4. Last ten items of the object set drawn by a right hander.